A

MANUAL

OF

HUMAN MICROSCOPIC ANATOMY,

BY

A. KÖLLIKER,

PROFESSOR OF ANATOMY AND PHYSIOLOGY IN THE UNIVERSITY OF WÜRZBURG.

WITH

TWO HUNDRED AND FORTY-NINE ILLUSTRATIONS.

LONDON:
JOHN W. PARKER AND SON, WEST STRAND.
1860.

LONDON:
PRINTED BY WERTHEIMER AND CO.,
FINSBURY CIRCUS.

TO

HIS DEAR FRIEND,

PROFESSOR W. SHARPEY, Sec. R.S.

IN GRATEFUL REMEMBRANCE OF MUCH KINDNESS AND

ENCOURAGEMENT,

AND

IN TOKEN OF HIGH AND SINCERE ESTEEM,

THIS WORK IS DEDICATED,

BY

THE AUTHOR.

[redacted]

PREFACE.

THE appearance of the present translation of my *Manual of Histology*, following on the excellent version issued by the Sydenham Society in 1853-54, may seem to require a word of explanation. The earlier translation, with which were incorporated various extracts from my *Microscopical Anatomy*, was from the hands of no less eminent editors than Professors *Busk* and *Huxley*. But having been printed exclusively for members of the Sydenham Society, the work has not obtained any large circulation in the English medical world. On this account, on my visit to the British Association at Glasgow in the year 1855, I was urged by several of my English friends to prepare an independent English edition, which should also have the advantage of a more compact form. After mature consideration, I resolved to act on this suggestion; and, in the same year, I succeeded in finding a publisher, *Mr. J. W. Parker*, ready to forward the work by all the means in his power. In carrying out my project, however, a considerable obstacle presented itself. The translation was executed under my own supervision by one of my pupils, who spared no pains or diligence upon it; but when submitted to English friends, on whose judgment I could thoroughly rely, it was pronounced to have followed too literally

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and should this publication succeed in rendering any service to scientific literature in England, it will be a peculiar gratification to me, to feel that I have repaid in some measure the obligations which I owe to that country, in which I have found so many sincere friends, and have gathered so much valuable instruction.

In conclusion, I cannot refrain from recording my grateful obligations to Messrs. *J. W. Parker* and *Son*, who have not hesitated to incur the additional expense of engraving anew all the woodcuts from my original drawings, and have, in every other respect, advanced the interests of my work.

A. KÖLLIKER.

WÜRZBURG, *April*, 1860.

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MANUAL

OF

HUMAN MICROSCOPIC ANATOMY.

INTRODUCTION.

§ 1. The doctrine of the elementary structure of plants and animals is the fruit of the last two centuries, and commences with *Marcellus Malpighi* (1628—1694), and *Anton van Leeuwenhoek* (1632—1723), at the period when, for the first time, high magnifying glasses, although still in a simple form, were put into the hands of investigators. The ancients and the observers of the middle ages knew nothing of the ultimate structural constituents of organism; for, although *Aristotle* and *Galen* speak of similar and dissimilar parts (*partes similares et dissimilares*) and *Fallopia* defines, still more accurately the idea of "tissues," and even attempts a classification of them (*Tractatus quinque de partibus similaribus* in Oper. Tom. ii. Francof, 1600), still the intimate conditions remained entirely concealed from these observers. Now, however brilliant the first steps of the young science were in the hands of the above-mentioned philosophers, and of *Ruysch*, *Swammerdam* and others, yet these men were not able to furnish it with a secure position, seeing that, on the one hand, investigators were still far too little acquainted with microscopical research, to be able to strive after the proper goal, and, on the other, were too much occupied with the cultivation of other branches, such as ordinary anatomy, physiology, embryology, and comparative anatomy. Thus it happened, that some isolated, and in part important, phenomena excepted, Histology made no material progress in the whole eighteenth century, and did not extend beyond an unconnected collection of individual observations (see *Fontana, Muys, Lieberkühn, Hewson, Prochaska*). It was first in 1801, that it was destined to *take up its proper position* among the anatomical sciences

by the genius of a man, to whom, indeed, Histology is not indebted for any great discoveries, but who, better than any before him, understood how to arrange the existing materials, and bring them into relation with physiology and medicine, so that it acquired for itself independence in all future time. In fact, F. X. BICHAT's *Anatomie Générale* (Paris, 1821), is the first scientific work on Histology, and on this account forms an epoch in its history. This work, besides, attained great importance from the circumstance, that in it the tissues are not only clearly defined and treated of most fully and logically in a morphological point of view, but are also discussed in detail in their physiological functions and morbid conditions. To this great internal progress were superadded, in this century, the increasing improvements of the external aids, the microscope, and a steadily growing zeal in the investigation of nature, so that it is not surprising that Histology has, within the last fifty years, left far behind all that was accomplished in the first century and a half of its existence. From the year 1830 more particularly, discoveries followed each other in such rapid succession, that it may be regarded as truly fortunate that they, at the same time, came in such connection together that microscopical anatomy escaped the danger of losing itself in details, as in former times. It was, namely, by *C. Th. Schwann*, in 1838, shewing that animal organisms are all originally composed of cells, and that their higher morphological structure arises from these elements, that the leading thought was promulgated which united all previous observations, and also proved itself applicable to further exertions. If *Bichat* founded Histology more theoretically by the laying down and consistent working out of a system, *Schwann* has, by his investigations, established it upon facts, and thereby won for himself the second laurel in this field. That which science has done since *Schwann* down to our own time, has been indeed of the greatest importance to physiology and medicine; and in fact, of high value even in a purely scientific point of view, in so far as many things only indirectly or shortly discussed by *Schwann*, such as the origin of the cells, the signification of the cell-nucleus, the development of the higher tissues, the chemical condition of them, etc., have been further advanced; but all these discoveries are not of a kind to lead us to any material extent into a new epoch. If, without pretending to be a prophet, it be allowed me to speak of the future, the condition of Histology will not advance until we succeed in looking essentially further into the depths of organic structure, and in *perceiving the elements, of which that which we at present regard as simple, is composed.*

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were the only possible or existing elements of animals. *Schwann's* ideas also of the origin of cells, although considerably modified and extended, have not been essentially altered, the cell-nucleus being always present as the principal agent of cell-formation and multiplication. We have advanced least with reference to the laws which prevail during the origin of the cells and higher elements, and our knowledge of the elementary processes during the formation of the organ must likewise be designated as being still very defective. Yet the proper path for clearing up these points has been taken; and a consistent investigation of the *chemical conditions of the elementary parts and of their molecular forces,* as it has been conducted by *Donders, Dubois, Ludwig,* and others, together with a more and more searching microscopical analysis of them which has been so useful in the nervous system and muscular fibres, and a *histological treatment of embryology* which has been attempted by *Reichert, Vogt,* myself and *Remak,* will certainly lift the veil more and more, and lead step by step nearer to the perfection of the science, although that may never be quite attainable.

§ 3. The aids in the study of Histology can only be shortly mentioned here. With regard to literature, the more important monographs will be found cited in the individual sections, and only the larger independent works will be enumerated here. SCHWANN'S *Microscopical Investigations on the Accordance in the Structure and Growth of Plants and Animals,* Berlin, 1839 (published in English by the Sydenham Society in 1847), deserves the first place, as the most fitting introduction to Histology. Besides, we have to mention X. BICHAT, *Anatomie Générale* (tom. iv. Paris, 1801); E. H. WEBER, *Handbook of Human Anatomy by Hildebrandt* (vol. i. *General Anatomy,* Brunswick, 1830)—an excellent work for that period, and even yet indispensably necessary, both as such and as a mine for the older literature; BRUNS' *Text-book of General Human Anatomy* (Brunswick, 1841)—very clear, concise, and good; HENLE, *General Anatomy* (Leipsic, 1841), with a classical exposition of our knowledge of the elementary parts in 1840, numerous original statements, and physiological, pathological, and historical remarks; G. VALENTIN, article "Tissue," in WAGNER'S *Handwörterbuch der Physiologie* (vol. i. 1842); QUAIN and SHARPEY'S *Anatomy* (3 vols. London, 1845—47, 6th edit. Lond. 1856)—the histological part done by *Sharpey* most excellently; R. B. TODD and W. BOWMAN, *The Physiological Anatomy and Physiology of Man* (2 vols. London, 1845—57)—based principally upon inves-

tigations of their own, very valuable; BENDZ, *Haandbog i den almindelige Anatomie* (Kiöbenhavn, 1846—47), with numerous historical reviews; A. KÖLLIKER, *Human Microscopical Anatomy or Histology* (2nd vol. *Special Histology*, 2 parts, Leipsic, 1850—54), with an exposition of the intimate structure of the human organs and systems; GERLACH, *Handbook of Histology* (2nd edit. 1853—54, Heft. i. and ii.); LEYDIG, *Histology, Human and Comparative* (Francfurt, 1857).

Besides these authorities, consult the *Jahresberichte* of *Henle*, in CANNSTATT'S *Jahresbericht*, and those of *Reichert* in MÜLLER'S *Archives*.

Pathological Histology, which is indispensably necessary for any one wishing to obtain a general point of view on Normal Histology, has but few comprehensive works to show. I may mention J. MÜLLER, *On the Intimate Structure and the Forms of Morbid Tumours* (Berlin, 1838); J. VOGEL, *Icones Histologiae Pathologicae* (Lips. 1842); GÜNSBURG, *Pathological Histology* (2 vols. Leipsic, 1845—48); LEBERT, *Physiologie Pathologique* (2 vols. Paris, 1845); J. WEDL, *Outlines of Pathological Histology* (Vienna, 1853). Besides these, the Treatises of *R. Virchow*, who of all living pathological anatomists has made the best observations, in his *Archives*, and in the *Wurzburg Proceedings*, are of the greatest importance.

Useful *Figures* are to be found in all the works cited above, with the exception of those of *Bichat, Weber*, and *Bruns*; further, the drawings of injections in BERRES' *Anatomie der Mikroskopischen Gebilde des menschlichen Körpers* (Heft. 1—12, Wien, 1836—42), are, for the most part, excellent; as also the representations of tissues and organs in R. WAGNER'S *Icones Physiologicae* (2nd edit.) contributed by *A. Ecker*. The drawings of C. J. M. LANGENBECK, *Mikroskopisch-anatomische Abbildungen* (Lief. 1—4, Göttingen, 1846—51); DONNÉ, *Cours de Microscopie* (Paris, 1844), with Atlas; A. H. HASSALL'S *Microscopic Anatomy of the Human Body* (London, 1846—49), and of MANDL, *Anatomie Microscopique* (Paris, 1838—48), are indifferent: on the other hand, those of QUEKETT, in his *Catalogue of the Histological Series in the Royal College of Surgeons of England* (London, 1850, vol. i.), are well executed. FUNKE'S *Atlas to Lehmann's Physiological Chemistry* (Leipsic, 1852), is also very good.

With regard to *Microscopes*, I am of opinion, that of the more readily accessible on the continent, those of *Oberhäuser* and *Nachet* rank highest. In Germany, *Plössl, Schiek*, and *Kellner*; in Italy, *Amici*; and in England, *Ross, Powell, Smith* and *Beck*,

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simple ones, and which are most fitly designated *higher elementary parts*. Such a coalescence has, hitherto, been observed only in cells with certainty, and many of the tubular and fibrous elements of the body proceed from it.

§ 5. *Fluid and solid intermediate Substances.*—Whilst in plants the elementary parts, in most cases, are directly united with each other, a special fluid, pulpy, or solid intermediate substance is very widely distributed in animals, which is often subservient to quite specific purposes, as the blood and the juices of glands, and is always ultimately derived from the blood, and more closely or more remotely related to it. When such an intermediate substance participates in the formation of the elementary parts, it may be called formative fluid, *cytoblastema*, Schleiden (from *κύτος vesicle,* and *βλαστήμα germinal material*), if it be present for the maintenance of them, it is denominated *nutritive fluid;* when, lastly, it has nothing to do either with the one or the other, it is designated *fundamental* or *connective substance.* The *cytoblastema* is usually *perfectly fluid,* as in the blood, chyle, many juices and glands, the contents of glandular follicles, and in many embryonic organs; more rarely *mucoid* and *viscid,* as in the gelatinous areolar tissues of embryos (see infra). The *nutritive fluid* occupies, in fully developed organs, the place of the formative fluid; and, except where it is contained in special canals and spaces, as in bones, teeth, and in many organs composed of connective tissue, is present in such a small quantity that it cannot be directly observed. A fundamental substance, lastly, occurs in the cartilages, and in the bones forming from these, also in the teeth, as a firm, or even bony, hard, homogeneous, granular, or even fibrous, connective mass of cellular elements, which arises partly as a secretion of the latter, partly from the blood independently of them.

The occurrence of a solid, fundamental substance, directly deposited from the blood, shows that all the solid parts of the body are not, without exception, formed from cells or in dependence upon them, as Schwann was disposed to assume. It is likewise certain, that in pathological formations such masses occur very extensively, the fibrinous exudations, especially, being capable of becoming transformed into permanent parts or tissues, without preliminary organisation, i.e. formation of cells.

A.—SIMPLE ELEMENTARY PARTS.

I.—Crystals, Granules, Filaments, Vesicles, Nuclei.

§ 6. When the simple elementary parts are compared with one another, there results an entire series of forms. The most simple of

also present themselves in a form which is also met with in inorganic nature, namely, as crystals and crystalline *granules*; yet, in man at least, such forms are very rare as normal histological parts (otoliths, calcareous particles in ossifying cartilages), while in animals, particularly in the invertebrate (siliceous and calcareous bodies of sponges, polypi, mollusca, etc., calcareous crystals in the brain and nerves of the batrachia), and in pathological formations (crystals of hæmatine, bilifulvine, cholestearine, calcareous concretions in joints), they are frequent phenomena. On the other hand, amorphous bodies consisting of organic substances, are very common; that is to say, in almost all animal fluids, whether contained in canals or inclosed in cells, as also in many firm tissues, there are found in various, even in enormous numbers, roundish granules, mostly of very small, scarcely measurable size. *Henle* has called them *elementary granules*, and expressed the supposition that they are vesicles. This, however, is not everywhere the case, inasmuch as it can be demonstrated that many of these corpuscles possess no envelope. To this category belong the fat drops which occur in many cells, and in numerous secretions of glands, the pigment granules of the black pigment of the eye, and of other coloured cells, the yelk granules of batrachian and plagiostomian ova, and the proteine granules found in most cells and juices of glands, as also in certain parts of the gray substance of the central nervous system. Of the pathological, yet very frequent formations, the granules of the colouring matter of the bile in the hepatic cells, the pathological granular pigment and the deposits of fat granules, as also the colloid-granules in the thyroid and other parts, and the *corpuscula amylacea* of the central nervous system, are also to be classified here, although they occasionally assume a very considerable size. All these granules are destitute of the phenomena which are observed in the higher elementary parts, as of growth from within outwards, of multiplication, of taking up and giving off material, and are, in so far, still very closely allied to the purely inorganic forms. Closely related to these formations are the *elementary fibres*, isolated finer or coarser fibres, which are developed without the co-operation of nuclei or cells by the differentiation of a homogeneous substance. Such fibres are met with in the matrix of many true cartilages, as also in many reticulated cartilages, and in many pathological formations, and may even present a growth in thickness by apposition, as in reticular cartilages.

Elementary Vesicles are likewise very frequent, and most of

[illegible] a physical, [illegible] however, *Harting* [illegible] cell from [illegible] certainly [illegible] with water [illegible] Besides, [illegible] chemical influence, [illegible] produce albumen- [illegible] membrane: and by [illegible] as has been observed [illegible]

[illegible]

§ 7. [illegible] elementary cells or nuclear cells, [illegible] of a line in [illegible] a special *envelope*, [illegible] and *contents* are to be distinguished. The latter always consist [illegible] and of formed particles of this or of that kind, and of a special roundish body, [illegible] which again contains fluid and a still smaller corpuscle, [illegible] in its interior. These cells, which are to be considered as being endowed with special vital powers, and capable of taking up and consuming matter, as well as of growth and of multiplication,

[illegible] not only solely constitute the body of the higher and of most of the lower animals in the first periods of life, but also almost solely produce the higher elementary parts of the fully formed body. Nay, even in fully grown animals, the elements are met with in very many places in the simple condition of cells; and, as such, participate more or less, often quite decisively, in the organic functions.

§ 8. A closer inspection of the condition of the cells shows the following. Their *fundamental form* is that of a sphere or lens, which belongs to all cells in their first period of life, to many, as especially those situated in fluids (blood corpuscles and others), constantly. The following forms appear more rarely: 1. The polygonal (pavement epithelial cells). 2. The conical or pyramidal-shaped (ciliated epithelium). 3. The cylindrical (cylindrical epithelium). 4. The fusiform (contractile fibre-cells). 5. The squamous (epidermic plates). 6. The stellate (nerve-cells). The

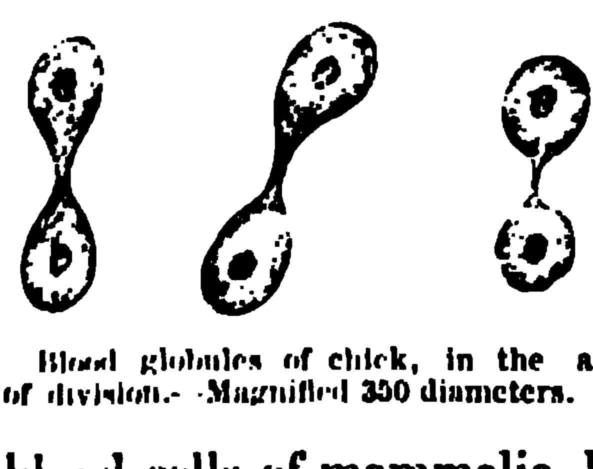
[illegible] take place on the ex- [illegible] example that the original [illegible] cartilage-cells.

[illegible]—With regard to the formation of cells, [illegible] between the *free origin* of [illegible] *of other cells.* [illegible] presented, the occurrence [illegible] and more doubtful: and it [illegible] as in plants, in dependence [illegible]. In this process of cell-multiplica- [illegible] either produce secondary cells, as they [illegible] multiply by division—[illegible] *cell-forma-* [illegible]. The cell-nuclei always play a very [illegible] of cells, and appear as the pr[illegible] formation for their evolution.

[illegible] plants, regarded the [illegible]—that by the intervention of [illegible] more and more [illegible] animals and plants agree. As for me, I [illegible] 1844; *Ann. d. sc. Nat.* 18[illegible] descendants of the [illegible] the yelk; and that even in the [illegible] consisting of cells, as in the [illegible]. Accordingly, I found [illegible] German *Handbook of Histo-l*[illegible] very much. Quite recently, *Virchow* (in [illegible] 1854, p. 329) has made known a series of facts, from the department of pathological anatomy, which show that in many places where formerly a free cell-formation was admitted, it does not occur. If to these facts are added the new observations of *Virchow*, with regard to the development of bones, as well as the recent investigations into the formation of the lymph-corpuscles, we may indeed conclude, that a free formation of cells does not anywhere exist.

§ 10. *Multiplication of Cells by Division*, is much more widely distributed than has hitherto been supposed; it being highly probable that the entire growth of the embryonal and fully developed cell-tissues, with the exception of cartilage, is solely effected by division. This process is easily observable in free cells suspended in fluid, as in the red and colourless blood-cells of mammalia, birds, and amphibia. Here, in elongating

Fig 2.



Blood globules of chick, in the act of division.—Magnified 350 diameters.

[illegible] formed in one cell several [illegible] the total contents of [illegible] same number of parts as there [illegible] a nucleus: and, lastly, [illegible] around these portions of [illegible] To this category [illegible] the development of the [illegible] in *Müll. Arch.* [illegible] of the yelk, a peculiar [illegible] the first development in [illegible] as an introduction to [illegible] embryo, and because [illegible] simple cell, comes under the [illegible] After the primitive nucleus of the ovular cell, the germinal vesicle, has disappeared [illegible], the granules of the yelk no longer form one compact heap as formerly, but become scattered and fill up the whole ovular cell. Then there arises, as the first sign of the commencing development, a new nucleus in the midst of the yelk around a new nucleus [illegible]. This is the first nucleus of the embryo, which, acting as a point of attraction upon the yelk, again unites it to form a spherical heap. In the further progress of development, there are formed from the first nucleus, by endogenous production, two new ones, which, as soon as they have become free by the resolution of the mother-nucleus, separate somewhat from one another, act as new centres upon the yelk granules, and thus the primitive heap breaks up into two. The multiplication of nuclei and yelk segments (the former always preceding the latter) then proceeds in a similar manner till a very large number of small segments are present, filling up the whole space of the yelk cell; it is only exceptional that the yelk segments do not break up until the nuclei have multiplied to three or four; so that three or four segments, instead of two, are directly formed from each of them. This process is called the *total cleavage*, because here the entire yelk becomes arranged around the newly formed nuclei; the *partial* cleavage essentially agrees with it, only differing in the

[illegible]

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selves or to *deposition* upon the outer surface of the cell-membrane.

The *Nuclei* and *Nucleoli* also participate in the growth of the cells to a certain degree; and the former, more especially, present, together with an omnilateral, an unilateral growth, in consequence of which they become elongated.

§ 13. *Processes taking place in the Interior of Cells.*—In order to obtain a clear insight into the processes going on in the interior of cells, it would be especially necessary to have a more accurate knowledge of the chemical properties of their contents than we now possess. Only two kinds of cells, the ovum and the blood-cells, have been more carefully investigated; but these are so peculiarly conditioned, that they can scarcely serve as types of cells in general. Nevertheless, from their analysis, some conclusion may be drawn as to other cells, and from such analysis combined with what micro-chemical investigation furnishes, we may, perhaps, be warranted in regarding cell-contents in general as a moderately concentrated solution of proteine, with alkaline and earthy salts and dissolved or suspended fat-particles. Many cells, however, differ very considerably from this, which is undoubtedly the ordinary condition of all cells, at least in the young state, in so far as in them some of the above-mentioned constituents preponderate very much, or entirely new substances are superadded. Thus, there are cells with much proteine, as the ganglionic globules; and with much fat, as the fat-cells, the cells of sebaceous glands, and the mammary glands, etc.; further, cells with hæmatine, pigment, constituents of the gall and urine, mucus (epithelial cells), serum (pathological fat-cells, corpuscles of connective tissue, lacunæ of bone), etc.

The phenomena manifested by these so variously constituted contents, during life, may be best designated as—absorption, assimilation, and excretion.

These are chiefly owing to chemical and physical causes, and may for the most part even be followed with the microscope, seeing that changes in the form and contents of the cell very frequently go hand-in-hand with them. With regard to absorption, it presents itself in all cells, and the primary cause of the entrance of material is simply to be sought in the capability of imbibition of the cell-membrane and contents. This imbibition is, however, not to be understood as if the cells admitted indiscriminately all substances approaching them; on the contrary, they present, according

to time and place, quite definite relations to the cytoblastema, rejecting one constituent of it and taking up another; and the same thing occurs with the absorptive power of those cells which possess contents from the first moment of their formation. That this is really the case, is, for example, proved by the circumstance, that in embryos, notwithstanding the uniform formative material, *i.e.* the blood-plasma, for all the cells, some take up more of these, others more of those materials, and from this results still more distinctly that the contents of probably all cells are chemically different from the cytoblastema by which they are formed and maintained, as has recently been more clearly demonstrated in ova and blood-corpuscles, the latter, for example, containing much more potass than the blood. The reason of this phenomenon may be thus stated in general terms, that the cell-membranes do not act like simple filters, but allow one substance or another to permeate them, according to their chemical composition, the nature of the surrounding fluid, their condition of aggregation, and their thickness. True *endosmosis*, which has frequently been assumed as occurring in the cells, does not, according to my observations, appear to occur, in as much as the cells in their totality rather present the condition of simple bodies saturated with fluid.

The substances composing and taken up by the cells, undergo manifold metamorphoses, in consequence of the vital process. These *metabolic phenomena* (*Schwann*) are referable, firstly to the *cell-membrane*, and secondly, to the *cell-contents*. With regard to the former, this much is certain, that the membranes of most cells not only become thicker and firmer with age, but also assume other chemical properties; yet it is impossible in the individual case to say to what the change is due. In the horny structures, the membranes of the young cells are readily soluble in alkalies and acid, whilst subsequently they resist it in part very much; the same thing is found in the higher elementary parts, as the nerve-tubes, animal muscular fibres, and the capillaries, in which the sarcolemma, the sheath of the nerve-tubes, and the capiliary membrane, which have the signification of metamorphosised cell-membranes, re-act quite differently from the primitive formative cells. In the cartilage-cells also the membranes become more resistent with age, and the same occurs with the cell-membranes of the ova of many animals, as is best shown in fishes. These examples, which might be multiplied, may suffice to establish the occurrence of metamorphoses of the cell-membranes; subsequent investigation will have to show upon what these de-

of a single cell, as shown by *H. Meckel* and others. In the department of pathological anatomy there belong to this category, the formations of pigment, the metamorphoses of the cells containing blood-corpuscles, the depositions of fat in cells of all kinds, etc.

Manifold [illegible] go hand in hand with these changes, such as the above-mentioned thickenings and laminated depositions upon the outer side of the cell-membranes; further precipitations in the cell-contents of granules of divers kinds, as of pigment, albuminous substances (many epithelial cells, hepatic cells, etc.), the formation of fat-drops, elementary vesicles, concretions, crystals and nuclei. Even *movements*, similar to the cyclosis of plants, appear to occur in cells of the lower animals (seen by me in cells of Polyclinum stellatum) and in Protozoa (currents in Loxodes bursaria, contractile vesicles in different genera); whilst on the other hand, the *Brownian molecular movement*, i.e. a more or less active tremulous motion of granules without any further *change of locality*, which is perceptible in many cells under the microscope (most distinctly in the pigment-cells of the eye) can scarcely be reckoned among the phenomena occurring during life.

§ 14. *Excretive Processes.*—The vegetative functions of animal cells are not merely confined to the taking up and transformation of matters, but materials are again set free, which are either further employed in some way, or are simply removed from the organism. In many cases, this takes place by the dissolution of the cells, as in many glands in which the mature secretion (milk, semen, cutaneous sebaceous matter, bile of the lower animals, ink of the *Cephalopoda*) consists, so to speak, of nothing else than the contents of the gland-cells. In other instances, the cells remain unaltered while they secrete substances externally, and thus the process presents itself in a two-fold manner.

1. *Cells may give off materials which they had taken up from without unaltered.* This is the case with the epithelial cells of the glands, which, like the kidneys, lachrymal glands, lungs, etc., simply allow substances to pass out of the blood, as also with the cells lining the surfaces of the serous membranes and of the external skin, and probably many others.

2. *Cells may separate substances which they have prepared within themselves.* Thus, the fat-cells give off fat in emaciating individuals; the cells of the liver, bile; those of the gastric glands, pepsine; those of the mucous membranes and glands, mucus. To this category also belong the secondary cell-membranes or the cartilage-capsules, lying external to the primitive cartilage cells, as

larger vessels, perhaps belong to this category, in so far as they appear to arise from the secretion of fluid in the interior of primitively compact cell-masses.

The application of the doctrine of the double cell-membrane in vegetable cells, the primordial utricle (*Mohl*) and cellulose membrane, to animal-cells, took place in 1852, contemporaneously and independently, by *Remak* (MÜLL. *Arch.* 1852, p. 63, *seq.*) and myself (*Handb. d. Geweb.* 1852, pp. 14, 29). Since this time, my observations on the cuticular structures (*Transact. of the Phys. Med. Soc. of Würzburg*, viii.) have shown that secondary depositions from the cells, analogous to the cellulose membrane of vegetable-cells, are to be found in a great many places, and are often characterised by a very particular structure, especially by the existence of a large number of extremely fine pores, pervading them in the direction of their thickness.

§ 15. *Animal Functions of Cells.*—To the vital phenomena of cells, also belong certain movements which appear in cells, of which it is extremely difficult to say whether they concern only the contents, or the cell-membranes also. They are most simple in those lower animals which have the signification of simple cells. Here there exists an entire group, *Rhizopoda* (*Amœba*, *Arcella*, *Difflugia*, etc.), the substance of whose bodies, without presenting a differentiation between envelope and contents, is capable of assuming the most diverse shapes. A similar amorphous "*contractile substance*" (*Ecker*), which also may be designated *Sarcode* (*Dujardin*), also occurs in the *Protozoa* provided with a special outer membrane (cell-membrane), and here occasions the changes of the contractile spaces, the movements of the pedicle of the *Vorticellæ*, and probably also the currents of the fluids, such as are found in *Loxodes bursaria*. In these animals, the outer envelope also appears to be contractile, either in its totality, or in its external processes, the cilia; yet it is also conceivable that all the movements are only dependent upon the contents, and that the envelope simply follows them as an elastic body. On this view, a cilium must be conceived as being a pedicle of a vorticella in miniature; in which latter, as *Czermák* shewed, the inner filament connected with the substance of the body is contractile, while the envelope is elastic.

In *the higher Animals*, contractile phenomena of this kind are found, firstly, in individual cells; and then in parts of tissues which owe their origin to a metamorphosis of single cells. To the former belong, 1. *Cilia*, external processes of cells, outgrowths which probably are not only to be regarded as prolongations of cell-membranes, but also of the contents; so that it cannot be , whether their power of contraction is to be referred to the

cesses which we cannot but consider as taking place in the nerve-cells, deserve the name of animal functions, since these processes are nothing else than what the physiologist understands as the functions of the gray nervous substance. We cannot, of course, enter into discussion of them here; and the more so since these functions are completely inaccessible to microscopical observation.

Donders was the first to assert the opinion, that only the contents of cells and not the cell-membranes are contractile; and, I must confess, that the longer I consider the subject, the more the idea of *Donders* pleases me; yet it appears to me as still rather premature, in entirely denying the power of contraction to cell-membranes, there being nothing *à priori* to adduce against this view, while a decision, founded on fact, cannot as yet be formed in many cases.

§ 16. *Metamorphoses of Cells.—Different Kinds of Cells.*—The destination of the cells which occur at earlier or later periods in the organism is very various. A very considerable number of them remain for only a short period in their original state, and, subsequently, unite with others for the formation of the higher elementary parts. Others, again, do not indeed enter into any such connections, but change more or less their former nature, as the horny plates of the epidermis and nails. Many cells, lastly, never go through any metamorphoses, but remain as cells, till they perish, sooner or later, often not till the destruction of the organism itself, such as epithelium-cells, the cells of glandular parenchymas, those of the nervous system, etc.

Permanent Cells may be arranged most conveniently under the following heads:—

1. *True Cells*, which have not altered their cellular nature in any essential point, occur in the epidermis (*stratum Malpighii*) epithelia, in the blood, the chyle, the lymph in gland-juices, adipose tissue, gray nervous substance, the red medulla of bone, in glands (liver, spleen, supra-renal capsules, closed glandular follicles) and in cartilages. These cells may be divided *according to their form*, into round, disc-shaped, cylindrical, conical, ciliated, and stellated: according to their *contents*, into cells containing fat, proteine, serum, haematine, biline, pepsine, mucus, and pigment: and, with regard to their *occurrence*, some are isolated either in *fluids* or *solid* tissues, while others are united to form *simple cellular parenchymas*; others, lastly, being connected by an intercellular substance of some kind.

2. *Metamorphosed Cells*, which have altered their original structure more or less. To this category belong—

2. *Higher Elementary Parts—the Formative Cells of which are no longer recognisable.*

1. *Fibres, Fibrous Networks, and Membranes of Elastic and Areolar Tissue.*

2. *Fibrous Networks of the Transversely-striped Muscles.*

3. *Fibres and Fibrous Networks of the Nervous Tissue.*

4. *Tubes and Plexuses of the Blood and Lymph Capillaries.*

5. *Terminations of the Tracheæ of Insects.*

All these higher elementary parts possess essentially the same properties as cells, especially *growth in length, and thickness, absorption, metamorphoses, and excretion of materials,* and, in part, *contractility,* as also other functions, which, perhaps, can likewise be demonstrated in cells. Growth manifests itself very distinctly in the circumstance, that all the above-mentioned elements immediately after their formation are invariably much shorter and narrower than at a subsequent period; the absorption of material is proved by the dependence of their functions upon the circulation, by the phenomena of absorption in the capillaries of the lymphatics and blood-vessels, and by the above-mentioned growth, which can only be conceived as taking place by the absorption of materials into the interior of these parts. A metamorphosis and excretion of materials may also be assumed along with these, as the well-known peculiar products of decomposition in the muscles, the changes of the muscular fibres and the nerve-tubes in altered nutrition and activity, as also the capillaries which are continually giving off the plasma of the blood, sufficiently testify. The muscular fibrillæ possess contractility; and the processes in the nerve-tubes, which, although they possess their analogies in part in the functions of the nerve-cells, are very peculiar, and, for the present, not to be more definitely characterized.

Literature of the Elementary Parts.—Besides *Schwann's* work, cited above, we may mention KÖLLIKER, *Die Lehre von der thierischen Zelle, in* SCHLEIDEN *und* NÄGELI'S *Zeitschrift für wissenschaftl. Botanik.* Part II. 1845. *Entwicklungsgeschichte der Cephalopoden,* 1844; and a Paper on Cuticular Structures and Pores in Cell-membranes, in *Transact. of the Würzb. Soc.* Vol. viii. REMAK. *Ueber extracellulläre Entstehung thier. Zellen und die Vermehrung derselben durch Theilung, und über Entsteh. des Bindegewebes, u. d. Knorpel,* in MÜLL. *Arch.* 1852. i.; as also the treatise of DONDERS, cited under Elastic Tissue; and the Embryological Monographs of REICHERT, BISCHOFF, VOGT, REMAK, and myself. Besides, compare the more recent comparative histological treatises of *H. Meckel, Leydig, Leuckart, Carpenter, Huxley, Gegenbaur, Meissner,* myself, and others.

[redacted]

II. OF TISSUES, ORGANS, AND SYSTEMS.

§ 18. The elementary parts of the simple and higher kinds are not scattered without order in the body, but united according to definite laws to the tissues and organs, as they are called. Under the former name is designated *every constant grouping of the elementary parts always recurring in the same way in analogous parts;* under that of an organ, on the other hand, is understood *a certain sum of elementary parts possessing a definite form and function.* When several or many organs of similar or different kinds unite to form a higher unity, the latter is called *a system.*

It is difficult to classify the tissues properly. When we only consider the conditions, such as they are, found in the adult organism, it is easy, indeed, to enumerate a gradually ascending series of simple to more and more complex formations. But in this way, formations which are closely related to each other would be torn asunder, and conversely. Better results are attainable, when, together with the fully developed form, we also take the origin and the chemical and physiological conditions into account, and from this point of view the following series of tissues may be constructed:—

1. Cell-Tissues.
   Epidermic tissue. Tissue of true glands.
2. Tissues of Connective Substance.
   Mucous tissue. Elastic tissue.
   Cartilage-tissue. Areolar tissue.
   Osseous tissue and Dentine.
3. Muscular Tissues.
   Tissue of the smooth muscles.
   Tissue of the transversely striped muscles.
4. Nerve-Tissue.
5. Parenchymatous Tissues of Vascular Glands.

The organs may be divided into simple and compound.

1. Simple Organs.
   1. Epidermis, epithelia, hairs, nails, enamel, lens.
   2. Simple true glands.
   3. Vitreous body.
   4. Chorda dorsalis, true cartilage, and elastic cartilage.
   5. Elastic ligaments and membranes.

6. Tendons, ligaments, fibrous membranes, fibro-cartilage.
7. Bones and teeth.
8. Smooth muscles and muscular membranes.
9. Transversely striped muscles and muscular membranes.
10. Nerves and ganglia.
11. Simple glandular follicles.

2. COMPOUND ORGANS.

12. Vessels.
13. Vascular membranes (external skin, mucous and serous membranes, proper vascular coats).
14. Special organs of the intestinal canal.
15. Compound true glands, with their individual sections.
16. Compound vascular glands (spleen, tonsils, supra-renal capsules).
17. Central organs of the nervous system.
18. Higher organs of the senses.

The organs lastly unite to form *special systems*, of which the following may be distinguished:—

1. *The System of the External Skin*, consisting of the corium, epidermis, the horny structures, and the larger (mammary glands) and smaller glands of the skin.

2. *The Osseous System*, comprehending the bones, cartilages, ligaments, and articular capsules.

3. *The Muscular System*, viz: the muscles of the trunk and extremities, the tendons, fasciæ, tendinous ligaments and bursæ mucosæ.

4. *The Nervous System*, consisting of the large and small central organs, the nerves and higher organs of the senses.

5. *The Vascular System*, consisting of the heart, the blood and lymph vessels, as well as the lymphatic glands.

6. *The Visceral System*, comprising the intestinal canal, the organs of respiration, with the thymus and thyroid, the salivary glands, the liver and spleen.

7. *The Urinary and Sexual Systems.*

Since the individual organs and systems will be spoken of in detail in the special part, we do not require to enter here into a more minute description of them; and it accordingly only remains to characterise the tissues themselves somewhat more minutely, while, at the same time, a few general remarks concerning the organs may be most fitly annexed.

[illegible] F. F. Thierfelder, *de Regeneratione Tendinum* [illegible] Langer, *die Anatomie der männlichen Brustdrüsen*, in [illegible] Leydig, *Unters. über Rept. u. Fische*, 1853, p. 112.

§ 23. *Mucous Tissue.*—By this name I designate a tissue which, in man, exists only in the vitreous body, but which has very probably an extensive distribution in the lower animals. It consists of cells and a soft matrix, or even only of the latter, as the cells may disappear in the course of development. The cells are round or oblong, and contain a variable amount of matter, rich in protein: while the matrix appears as a homogeneous or striated mass, and owes its greater or less consistency to the quantity of mucus in its composition, which mucus appears to be very different in different animals. In the vitreous body of the embryo and child, which organ as yet can alone be referred to this tissue, the cells are pretty numerous, and uniformly scattered throughout the whole organ; whilst in fully formed animals, they are to be found only at its surface, or are wholly wanting. When comparative histology is farther advanced, it will, doubtless, be found that many other organs consist of this tissue; and I may, for the present, bring under it the substance of the disc of Medusæ, that of the swimming bladder and other parts of the Siphonophoræ, etc. Farther investigation would also, without doubt, bring out a diversity of chemical composition; and it will, perhaps, be necessary hereafter to select a more general expression for this tissue.

The name *Mucous Tissue* was lately applied by *Virchow* to designate the gelatinoid embryonal connective tissue, and then extended to that of the vitreous humour. In normal histology, there seems, for the present, no reason for assigning a place to a form of tissue of the composition of gelatinoid-connective tissue, since such a one never occurs in the fully developed body. I have, accordingly, reckoned only the vitreous body under the present head in the mean time. If, however, such a tissue shall be found to be permanent in animals, or the requirements of pathological Histology shall so demand, the definition given above can be readily enlarged, and a tissue classified under it, in which one part of the cells has become converted into a network, while the others have remained lying in the muciferous (albuminiferous) jelly.

Literature.—Compare the treatises of *Virchow*, cited in § 23, then of the same author; *Notiz über d. Glaskörper im Arch. f. path. Anat.* iv. p. 468. and v. 278.

§ 24. *Cartilage-Tissue.*—The cartilages consist of a firm, but elastic, bluish, milk-white, or yellowish substance, which, in point of structure, presents a two-fold condition; and appears, firstly, *as a simple parenchyma of cells;* and, secondly, *as a cell-tissue with a matrix between the elements.*

in the orbit; around the kidneys; in the mesentery and omenta; around the spinal cord; on nerves and vessels; and in muscles.

m. Ordinary areolar connective tissue, which is sometimes quite poor in elastic fibres and plasm-cells, and sometimes abounds in them, is found most extensively between the organs seated in the neck, the thoracic, abdominal, and pelvic cavities; along the course of all vessels and nerves; and in the interior of muscles, nerves, and glands.

In certain places, as in the vertebral canal and medulla of cartilage, it is of a *gelatinous nature,* like embryonal loose connective tissue, and then contains in its meshes a fluid sometimes like serum, sometimes containing mucus and albumen.

Literature.—ZELINSKY, *De Telis Collam Edentibus.* Dorp. 1852. Diss. Also the treatises cited in § 224.

§ 27. *Osseous Tissue.*—Structurally, osseous tissue essentially consists of a matrix, and of numerous microscopic cavities 0·006‴ to 0·014‴ in length, 0·003‴ to 0·007‴ in breadth, and 0·002‴ to 0·004‴ in thickness, disseminated in it,—the *lacunæ* (bone corpuscles of authors). The former, which is of a white colour, is sometimes more homogeneous, sometimes finely granular, very frequently lamellated, and, from its intimate union with calcareous salts, hard and brittle.

The lacunæ are generally lenticular in shape, and are, in most cases, connected to each other by numerous fine processes, the *canaliculi,* by which some of them also open upon the outer surface of the bones, and others into the larger and smaller medullary spaces in the interior. The lacunæ and canaliculi contain a pellucid matter, which may be designated as the nutrient fluid of the bones; and, in many cases, a cell-nucleus also appears to be enclosed in the lacunæ, and may, perhaps, be present in all. Besides these two most important elements, which are never absent in the bones of the higher animals, most of the bones contain numerous *vessels* and *nerves,* and frequently, also, a special substance supporting these, the *medulla.* This consists either of ordinary *adipose tissue,* or of a loose, scanty areolar tissue, with but few fat-cells and numerous proper marrow-cells, as they are called. These soft parts fill up the large central cavities of the bones, and those of the spongy substance; they also, at least in part, occupy the narrow canals traversing the compact substance, the *vascular* or

ossification of a new-formed soft substance, the matrix of cartilage being thus used; in the other, by the deposition of calcareous salts in the fibrous substance of connective tissue, but presents in both cases, as far as is known, essentially the same chemical and histological characters. The *nutritive changes* of the bones are very energetic, and are accomplished through the agency of the vessels of the periosteum, and by those of the marrow and Haversian canals, when they exist. The bones possess a great capability of regeneration, so that they readily re-unite when broken; and extensive losses of substance may be repaired, or even entire bones restored, when the periosteum has been spared. Accidental formations of bone are also very common.

Osseous tissue occurs, first, in the bones of the skeleton, to which belong, also, the auditory ossicles and the hyoid bone; secondly, in the bones of the muscular system, as the sesamoid bones and the ossifications in tendons; thirdly, in the *crusta petrosa* or *cement* of the teeth. Many cartilages ossify pretty regularly in old age, as the costal and laryngeal cartilages.

Dentine, or *ivory*, may be regarded as a modification of osseous tissue, in which, instead of isolated lacunæ, long canals, the *dentinal tubes*, occur, and which, also, presents some differences in chemical composition. The mode of its development leads us to regard it as an osseous substance, whose cells have grown out into long tubules which anastomose with each other by fine processes; a view which also explains the numerous formations observable in animals between the typical dentine and osseous tissue (see below, the section on the Teeth).

It has been supposed till now, that the stellated bone-cells in part arise from cartilage-cells, in part from cells of connective tissue; but *H. Müller* has shown, in a very remarkable paper, that true cartilage-cells never are transformed into real stellated lacunæ, and that these arise only from the cells of connective tissue, and from a young growth of cells, formed by a multiplication of the cartilage cells. The only exception of this rule seems to occur in rachitic bones, in which, as I have shown, cartilage-cells are metamorphosed into peculiar stellated lacunæ.

Literature.—DEUTSCH, *De penitiori Ossium Structurâ Observationes Diss.* Vrat. 1834. MIESCHER, *De Inflammatione Ossium eorumque Anatome generali.* Berol. 1836. SCHWANN, Art. *Knochengewebe*, in *Berl. Encyclop. Wörterb. der med. Wiss.*, vol. xx. p. 102. TOMES, Art. *Osseous Tissue*, in *Cyclop. of Anat.*, iii. H. MÜLLER, in *Zeitsch. f. Wiss. Zool.*, Bd. ix.

developed during pregnancy, and attain up to ¼ of a line in length, in the vagina, in the cavernous bodies of the external genitals, and in the broad ligaments of the uterus at various places.

8. In the *male sexual organs* they occur in the *dartos*, between the *tunica vaginalis communis* and *propria*, in the *epididymis*, the *vas deferens*, the seminal vesicles, the prostate, around Cowper's glands, and in the *corpora cavernosa* of the penis.

9. In the *vascular system*, smooth muscles are met with in the tunica media of all arteries, especially the smaller ones, in that of most veins, and of the lymphatic vessels, except the finest; further, in lymphatic glands (*Heyfelder*), and in the external or adventitious coat of many veins. The muscular elements in vessels of middling size are everywhere fusiform fibre-cells; in the large arteries, on the other hand, they are short plates, often resembling certain forms of pavement epithelium, and in the smallest arteries, oblong, or even roundish cells; both of which forms are to be regarded as being more undeveloped.

10. In the *eye*, smooth muscles form the sphincter and dilator of the pupil and the *tensor choroideæ*.

11. In the *skin*, this tissue, besides entering into the formation of the *dartos*, occurs in the form of small muscles attached to the hair follicles, also in the areola of the nipple, in the nipple itself, and in many sudoriparous and ceruminous glands.

Formerly, the elements of the smooth muscles were regarded as long bands, containing numerous nuclei, and, like the transversely striped fibres, were considered as arising by the coalescence of many cells arranged in series. In 1847, I showed that this is not the case; but that, on the contrary, the elements of these muscles are only simple, modified cells; and demonstrated, at the same time, that these contractile fibre-cells occur wherever contractile connective tissue has been assumed to exist, and are also to be met with in other parts where they were not supposed to exist.

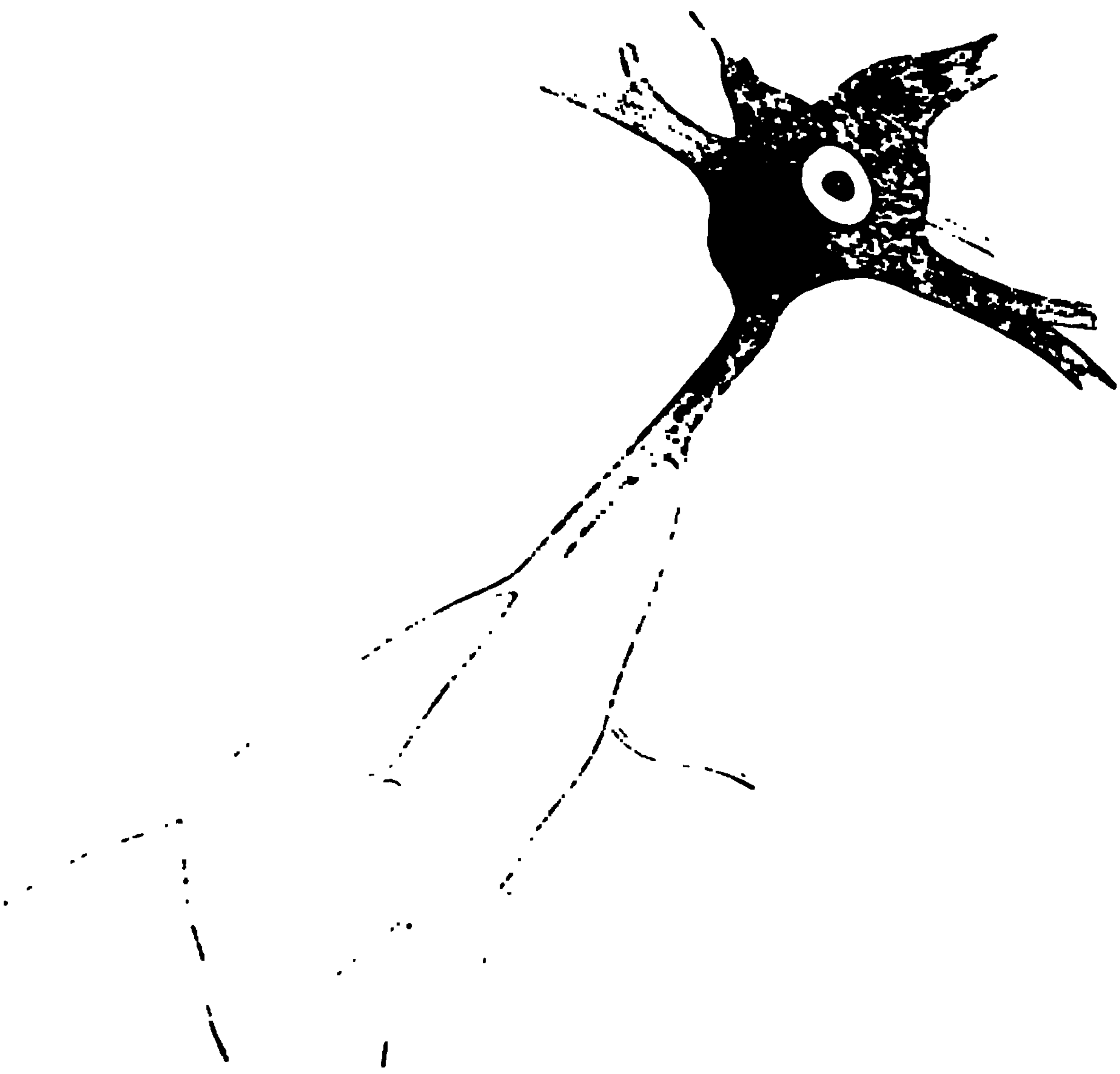
Literature.—KÖLLIKER, *Ueber den Bau und die Verbreitung der glatten Muskeln.*, in the *Mittheil. der Naturf. Gesellschaft in Zürich*, 1847, p. 18; and *Zeitschrift für Wissenschaftl. Zoologie*, vol. i., 1849. LISTER, in the *Micros. Journal*, and *Trans. of Royal Society of Edinburgh.*

§ 30. *Tissue of the Muscular Fibres, or Transversely Striped Muscles.*—The elements of this tissue consist essentially of *muscular fibres*, or *muscular primitive bundles*, as they are called, each of which represents a bundle, 0·004‴ to 0·03‴ in thickness, of fine fibrillæ, enclosed by a special, homogeneous, delicate, elastic envelope, the *sarcolemma*. The fibrils are generally regularly nodular, appearing, as it were, to consist of a number of particles

inasmuch as, while they have precisely the aspect of non-medullated nerves, they often run to great distances, and, at the same time, ramify variously. How these processes ultimately terminate, whether free or by connection with nerve-fibres, or by anastomoses with similar processes, is not yet made out; but it appears not improbable, that all these three possibilities occur in different situations.

Nerve-fibres and nerve-cells unite to form two substances, very differently constituted in their extremes, the *grey and white substance*. The latter forms the *white medulla*, as it is called, or the

Fig. 29.



Large nerve-cell, with processes, from the anterior cornua of the human spinal cord. Magnified 350 times.

medullary matter of the spinal cord and brain, and the nerves; and consists essentially of fascicularly arranged or interwoven nerve-tubes, to which, in the peripheral nerves, a special envelope of connective tissue, the *neurilemma*, as it is called, is superadded. The *grey substance* chiefly contains nerve-cells, and, in certain places, a finely granular matrix and free nuclei. It very rarely, however, occurs quite pure, but is generally intermingled, more or less, with nerve-tubes. This is especially the case in the majority of the ganglia, in the grey substance of the spinal cord, and in the so-called cerebral ganglia; while, on the other hand, in the grey cortex of the brain and cerebellum, it is, in some places, almost destitute of nerve-fibres. This substance is much more largely

zu den Nervenfasern, Leipzig, 1847. CH. ROBIN, in *l'Inst.*, 1846, Nos. 687—690; and 1848, No. 733. KÖLLIKER, *Neurologische Bemerkungen*, in *Zeitsch. f. wiss. Zool.*, i. p. 135.

5. TISSUE OF THE VASCULAR GLANDS.

§ 32. Under the name *vascular glands* are comprehended a series of organs whose common character consists in this, that they prepare, from *the blood or other juices in a special glandular tissue*, certain matters which are not conveyed away by special permanent, or occasionally-formed excretory ducts, but simply by transudation from the tissue, and are then employed, in one way or another, for the purposes of the organism. Although this very general definition may include organs which it will, perhaps, be necessary hereafter to separate, yet, owing to our very defective knowledge of these structures, it seems to be the only one possible, without too much anticipating the special discussion of them.

The essential glandular tissue of the organs in question presents itself in the following forms:

1. *As a parenchyma of larger or smaller cells*, embedded in a *stroma* of connective tissue. *Supra-renal capsules, anterior lobe of the pituitary body*. Here the cells attain 0·04''', and more in size; and then contain, besides a granular mass, numerous nuclei and secondary cells.

2. *As closed follicles*, with *an envelope of connective tissue* and contents consisting of *nuclei, cells*, and *some fluid*. To this division I reckon:

a. The *solitary follicles* of the stomach and intestine; and

b. The *aggregated follicles* of the small intestine, or the patches of *Peyer* (in animals, also, of the stomach and large intestine), both of which contain numerous blood-vessels in the interior of the follicles.

c. The *follicular glands of the root of the tongue, the tonsils*, and *the pharyngeal follicles*, which contain, in the walls of their cavities, numerous shut follicles like the above-mentioned, and probably, also, having vessels in their interior.

d. The *lymphatic glands*, the glandular parenchyma of which consists of round follicles, similar to those of the Peyerian glands, but opening into each other, and directly connected with the lymphatic vessels.

3. *As a cell-parenchyma, supported by trabeculæ of connective tissue*, containing, like the above, *numerous closed follicles*. *Spleen*.

The chemical nature of these more or less vascular organs is

... and their yellowish-red, ... eye. In the *nipple* ... particularly, and be- ... form a dense network, ... of the milk-gland ...

... in the super- ... corium, in all ... occur (fig. 34), in the ... roundish bundles ... of a line broad ... exception, either ... lie alongside of ... and sebaceous ... These muscles arise from ... portions of the ... beneath the *epidermis* ... by means of several little ... small tendons (*Lister*) ... towards the hair-follicles ... attached to the former ... their base.

... cells is pre-eminently the ... lie here in the form of ... larger or smaller masses or lobules ... of the areolar tissue. Each fat ... connective tissue, in which the ... and consists either of a single ... of a variable number of smaller and ... of which again has a delicate covering of its own.

Two fat-cells, from the medulla of the human femur. *a.* Nuclei; *b.* membranes of the cells; *c.* fat-globule. Magnified 350 times.

According to *Todd* and *Bowman*, every cell has its special covering and vessels; but although this is true in many cases, it certainly does not apply to all. In the corium the fat-cells prevail most in the deeper portions around the hair-follicles and glands, and they are altogether wanting in the papillary layer. In individuals in moderately good condition the fat-cells are invariably round or oval, from 0·01‴ to 0·06‴ in diameter, dark contoured, and filled with fluid pale yellow fat, in the form of a single drop

scrotum and of the skin of the penis, the erection of the nipple, and the occurrence of the so-called goose-skin, *cutis anserina.* This depends upon the above-described smooth muscles of the skin, which, as *Froriep*, and afterwards *Brown-Séquard* and I have found, contract under the influence of electricity; for even in the living subject the cutis anserina and erection of the nipple, and in the bodies of executed persons a wrinkling of the *scrotum*, can be effected by that stimulus. During the erection of the nipple by means of gentle mechanical stimulation, the entire *areola* diminishes by the contraction of its circular fibres, and thus pushes forwards the nipple itself, whose fibres, in this case, appear to be relaxed. Under the influence of cold the nipple and its areola contract, and both become small and hard. The *cutis anserina*, which consists in local contractions of those parts of the skin seated around the hair-follicles, by which the openings of the follicles are pushed forwards conically, can be easily explained by means of the muscles found by me, which extend from the superficial parts of the *corium* downwards to the hair-follicles, and when they are in activity, protrude the follicles, and draw in those parts from which they take their origin. The assumption of a contractile connective tissue in the skin, as also in other parts, I must, as formerly (*Mittheil. der Zürcher Naturf. Gesellschaft*, 1847), decidedly reject, because the existence of smooth muscles, demonstrable by the microscope in the skin, whose contraction under the influence of galvanism can be shown by experiment, sufficiently explains all the phenomena of contraction exhibited by the skin.

With reference to the office of the touch-bodies, *Meissner* has, in his larger work, expressed the opinion, that they are subservient to a specific function, which is only met with in the hands and feet, *that of the simple sensation of touch*. This is defined as the simple perception of an external object, without the sensation of pressure; but in a later work (*Zeitschrift f. rat. Med.*, 1854, page 260), is designated as 'Perception of pressure by means of the touch-bodies.' No one will blame the able discoverer of the touch-bodies, in endeavouring to ascribe to them an important physiological function; but, upon the other hand, no unprejudiced person will be induced to declare the perceptions of pressure, which we experience in the palm and sole (apart from their delicacy), to be different from those which we receive from other nerves of the skin.

B. EPIDERMIS.

§ 42. The corium is, in its entire extent, covered by a semi-transparent membrane, which is destitute of vessels and nerves, and composed entirely of cells — the *epidermis*. This is closely

The diameter of the medulla is, in general, to that of the hair itself as 1 to 3—5: it is relatively and absolutely thickest in short thick hairs, thinnest in woolly hairs and those of the head. In a cross section it has a round or flattened figure; and the cells which compose it are arranged in 1—5, or even more longitudinal rows.

According to *Reissner* and *Reichert*, the medulla contains in its interior a fine fibre, which is a prolongation of the hair-papilla; a statement which I have not hitherto been able to confirm.

§ 60. The *cuticle of the hair* is a very thin transparent membrane, which forms a complete covering for the hair, and is very firmly united with the cortical or fibrous substance. When viewed in its normal position and in an unaltered hair, its almost sole indications are numerous, dark, reticulated, irregular, and even jagged lines, which are distant 0·002‴ to 0·006‴ from each other, and extend round the hair, and small projections giving a serrate outline to its apparent border (fig. 49, A.). If a hair be treated with alkalies, the cuticle separates in larger or smaller shreds from the fibrous substance, and even breaks up into its elements. These are quite flat, non-nucleated plates, generally transparent and pale at the borders, and of a quadrangular or rectangular outline, which do not swell up into vesicles by means of re-agents. They are arranged like tiles on a roof, the lower cells overlapping the upper ones, and form a simple membrane, which entirely envelopes the cortex or fibrous part of the hair. In sulphuric acid, also, the structure of the cuticle can be easily perceived; the hair becomes ragged at the borders, from the projection of the plates, and then the cuticle can be easily scraped or rubbed off; but it is reduced to its constituent elements, and it is not easily obtained in larger patches.

Fig. 49.

A. Surface of the shaft of a white hair, magnified 160 times. The curved lines designate the free border of the epidermic plates. B. Epidermic plates from the surface, isolated by caustic soda, and magnified 350 times. Either one or both of their borders are folded, and consequently appear dark.

The cuticle consists of a single layer of plates or scales, which on the shaft is 0·002‴ to 0·003‴, on the root 0·0025‴ to 0·0035‴ thick; the plates measure, in the transverse direction, 0·024‴ to 0·28‴; in the longitudinal, 0·016‴ to 0·02‴; and are scarcely thicker than 0·0005‴. At the hair-bulb these plates pass rather

isolated, so as to be positively recognised as spindle-shaped fibres with a single nucleus, so that I cannot, for the present, express myself decidedly as to their nature; and the more so, as we have no facts to show that contractions of the hair-follicles take place.

The third layer is a *hyaline structureless membrane*, which, when the hair is pulled out, always remains behind in the hair-follicle, and, in connection with and also covering the papilla [illegible] extends from its base as far as the internal root-sheath, and perhaps higher. It appears, in the uninjured hair-follicle, only as a very pale streak, 0·001''' to 0·0015''', seldom 0·002''', in thickness, between the external root-sheath and the transverse fibrous layer of the hair-follicle; but, by preparation of an empty hair-follicle, it may be easily obtained in considerable patches. It then appears smooth externally, but internally presents very delicate, transverse, often anastomosing lines, which, like the membrane itself, are not altered by diluted acids or alkalies. Neither alkalies nor acids cause cells or nuclei to appear in this membrane, and it belongs, accordingly, to the class of the true structureless membranes.

The *papilla of the hair*, less fitly termed hair-germ (*pulpa pili*), belongs to the follicle, and represents a papilla of the cutis. It is a beautiful ovate or fungiform papilla, $\frac{1}{8}'''$ to $\frac{1}{16}'''$ broad, $\frac{1}{11}'''$ to $\frac{1}{5}'''$ long, and is connected by a pedicle with the connective-tissue-coat of the follicle; it has a sharp outline, and a perfectly smooth surface; in its structure, it harmonises completely with the papillæ of the cutis, and consists of an indistinctly fibrous connective tissue, with scattered nuclei and fat-granules, but without cells. It contains, also, in man and in animals, vessels; but no one has as yet been able to demonstrate nerves in it.

§ 63. The *root-sheath* may be divided into an external and an internal layer, of which the former is continuous with the epidermis round the opening of the hair-follicle, and appears as the epidermic lining of the follicle; while the internal is an entirely independent layer, and enters into direct relation with the hair.

The *external root-sheath* is a continuation of the mucous layer of the epidermis, invests the entire hair-follicle, and rests in its lower half on the above-described structureless membrane; higher up, where the latter and the transverse fibres are no longer present, it lies immediately upon the longitudinal fibrous layer. In structure, it corresponds entirely with the mucous layer; like

[illegible] between them. These (fig. [illegible] layer (*Huxley's* layer), [illegible] above described (0·014‴ to [illegible]) likewise, however, poly-[illegible] half of the root-sheath, [illegible] 0·006‴. The [illegible] root-sheath amounts, on an average, [illegible] evident that its cells, which at [illegible] to 0·005‴ in thickness. [illegible] in their natural position, [illegible] they are easily isolated in soda [illegible] swelling up — a character which, as [illegible] the actions of alkalies in [illegible] plates of the hair.

[illegible] the proper inner root-sheath

Fig. [illegible]

[illegible] root-sheath, magnified 350 times. A. From the outer layer. 1. [illegible] 2. the same in connection, from the uppermost parts of the [illegible], after treatment with caustic soda. *a.* Openings between the cells *b.* B. Cells [illegible] layer, with elongated and slightly dentated nuclei. C. [illegible] part of the inner sheath, which consists of a single layer.

consists of only a single layer of beautiful, large, polygonal, nucleated cells without openings between them, which, becoming at last soft, delicate, and roundish, pass into the external layers of the round cells of the hair-bulb, without any sharp line of demarcation. Superiorly, this investment is not unfrequently somewhat separated from the hair. It terminates near the openings of the sebaceous glands in a sharp, dentated border, which is formed by

[illegible] the eyelashes. The hair- [illegible] other parts of the body of the [illegible] hair: but this, [illegible] unaccompanied by [illegible] which precedes the shedding of [illegible] common in [illegible] I believe I am [illegible] these processes I infer the [illegible] and especially since [illegible] the hairs of the head fall [illegible] are replaced by [illegible] will be necessary to [illegible] change of the hair takes [illegible] and whether repetitions of the [illegible] later period.

[illegible] the new hairs are likewise [illegible] of *Heusinger* and [illegible] and *Schultze* show; [illegible] *Langer* does not [illegible] appear to be exactly the same [illegible]

[illegible] —The hairs possess a determinate [illegible] the sex of the individual, [illegible] with the other horny [illegible] the growth of hair proceeds is, [illegible] Here new elements [illegible]—through means of a blastema [illegible] of the hair-follicle itself—by the [illegible] cells there situated, while the [illegible] somewhat higher placed, are [illegible] into the cells of the [illegible] the plates of the fibrous [illegible] epidermic scales; and thus the [illegible] continually pushed from below upwards, and elongated. In the latter no formation of elementary parts occurs, at most only a certain alteration of those already existing, which causes a gradual thinning of the root from the bulb upwards, until it is reduced to the thickness of the shaft. Higher up even these changes of the elementary parts are wanting; consequently hairs, when cut, do not acquire new points. The root-sheaths and the outer layer of the hair-cuticle do not take part in the growth of cut hairs.